THE CHEMISTRY AND THE CHEMICAL EXPLOITATION OF WESTERN AUSTRALIAN PLANTS

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CONTENTS.

		Page
I.	Introduction	83
II.	Essential Oils	85
	Family Santalaceae	85
	Family Myrtaceae	85
	Family Rutaceae	87
	Family Labiatae	87
	Family Coniferae	88
	Other Families	88
III.	Resins and Gums	89
IV.	Tannins and Kinos	90
V.	Poison Plants—	
	(a) Glycosides	91
	(i) Cyanogenetic Glycosides	91
	(ii) Saponins	92
	(iii) Other Toxic Glycosides	93
	(b) Alkaloids	93
	(c) Plants containing Nitrates	96
	(d) Photosensitising Plants	97
	(e) Fish Poisons	97
	(f) Miscellaneous Poisons	98
VI.	Dyes and Colouring Matters	99
VII.	Vitamins	100
VIII.	Medicinal Substances	100
IX.	Wood Distillation	101
X.	Conclusion	102
	References	103

I. INTRODUCTION.

Investigations of plants which are concerned directly or indirectly with their chemical composition are carried out by a variety of workers, including the chemist, plant physiologist, pharmacologist and agricultural chemist. In all such work, however specialised, collaboration with other scientific workers is essential, more particularly with the botanist, for incorrect identification and naming of species invariably leads to much unnecessary labour. The researches of these workers are never directed towards painting a complete picture of the chemical composition of a plant, but are normally aimed at the isolation of a pure product of some scientific or medicinal value or the identification of some toxic substance. It is perhaps fortunate that this is so because of the difficulties which arise in such investigations.

Such difficulties as are inherent in the variety, complexity and often the instability of the substances being handled, as well as the inaccuracy of many quantitative methods of analysis, are readily appreciated by the chemist. The magnitude of the work, however, is increased considerably by seasonal or even diurnal variation in the composition of plants, by variation in different parts of an individual plant and by variation due to changes in climate, soil and cultivation. To these must be added the problems associated with the occurrence of physiological forms, or variants, of an individual species.

The term physiological form is applied to morphologically indistinguishable plants which are known to exhibit constant differences in their chemical composition, which differentiate sharply between them. Many such examples are known in the Australian flora, particularly amongst the oil-bearing plants examined by Baker and Smith, formerly economic botanist and economist chemist respectively of the Sydney Technological Museum, and by Penfold, the present curator and economic chemist of the same institution. Physiological forms occur in *Melaleuca uncinata* R. Br. (p. 86), *Eucalyptus campaspe* S. Moore and possibly in *Duboisia Hopwoodii* (F. Muell.) F. Muell. (p. 94).

The importance of the occurrence of such variants lies in the facts that, firstly, essential though it is in any phytochemical work, correct botanical identification does not necessarily tell the full story of the chemical composition of a plant; secondly, the results of the chemical examination of a plant cannot necessarily be applied to an apparently identical plant growing in other districts, regions or countries; and thirdly, the existence of variants may be of considerable importance if commercial exploitation of a plant is to be undertaken.

Provided allowance is made for the possible existence of physiological forms and for variations due to climate, soil and cultivation, a knowledge of the flora of botanically related countries is of value in any phytochemical problem. While, at the present time, it may not be possible to explain the origin of the Australian flora, it is apparent that certain elements of it have originated in pre-existing floras which have become widely distributed (1). Firstly, there is an element of southern derivation, either antarctic or subantarctic, which is shared with New Zealand, South America and South Africa. Secondly, there is a paleotropic element which, originating in Asia, has migrated not only to Australia through India, Malaya and the East Indies, but has also travelled down the east coast of Africa. We may therefore look to the floras of the countries surrounding the Indian Ocean, of Melanesia and New Zealand and of South America for information and suggestions concerning many of our own plants. To these two elements must be added a third, an Australian element, which is most richly developed in the stable environment of South Western Australia.

Much information concerning the chemistry of many indigenous and some introduced plants in this State is contained in scientific publications of South Africa and India and there is also a wealth of suggestion in the folk-lore of the native races of these two countries and of the natives of East Africa as well. In the Eastern States of Australia, the chemical investigation of plants is being pursued in many institutions and the accumulation of knowledge of the practices of the aborigines normally proceeds with reasonable speed. It is regrettable that in Western Australia so little chemical work has been done up to the present, not only on the elements of our flora which are common to other countries, but perhaps more especially on those plants which are almost restricted to this part of the world. It is also unfortunate that there does not appear to have been any sustained effort made to build up a knowledge of the foods, medicinal substances, etc., which are used by our own native tribes in the different parts of the State.

It is not possible, in a review such as this, to adopt a purely chemical basis for discussion of the topics dealt with and the subject matter has therefore been divided into such sections as essential oils, resins and gums, tannins and kinos, poison plants, dyes and colouring matters, vitamins and medicinal substances.

II. ESSENTIAL OILS.

Family Santalaceae.

Sandalwood, the heart wood of *Santalum spicatum* (R.Br.) DC., was first exported from Western Australia in 1845 but it is difficult to fix a date when the oil was first marketed. There was intermittent production of the oil by a number of small distillers about sixty years ago, but it was not until 1921 that systematic and scientifically controlled production of the oil was commenced. Prior to this, the alcohol content of the highest grade oil produced was about 75 per cent., but by 1926 this figure had been increased to 93 to 95 per cent. (2), resulting in the inclusion of the oil in the British Pharmacopoeia. The total santalol content of this oil (that is α — and β —santalol) was only about 45 per cent., but since then, while the high percentage of total alcohols has been maintained, the santalol content has been increased to 60 to 65 per cent. The nature of the remaining alcohols in the oil of *S. spicatum* is not known and the elucidation of their chemical structure is a problem which requires solution (3).

The oil of *S. lanceolatum* R.Br. is also distilled to some extent, on account of its higher laevo-rotation, for blending with the oil of *S. spicatum*. It has been shown (4) to contain the primary sesquiterpene alcohol lanceol.

Family Myrtaceae.

The oils of many of the species of *Eucalyptus* occurring in the Eastern States of Australia have been thoroughly investigated, but, of the 140 to 150 species known in Western Australia, less than 40 have been examined and not all of these in any detail. The oils consist chiefly of terpene and sesquiterpene compounds associated with more or less oxygenated derivatives such as cineole, alcohols, esters, aldehydes, acids, ketones and phenols, or possibly keto-enol compounds which give colours with ferric chloride. The hydrocarbons present are chiefly pinene and phellandrene, generally accompanied by aromadendrene and occasionally by *p*-cymene and terpinene. The alcohols include geraniol, terpineol and eudesmol, and in some cases they make up an appreciable amount of the oil. These species are not as highly evolved as some of those found in the Eastern States and they include such primitive types as *E. calophylla* R.Br. and *E. diversicolor* F. Muell., the oils of which consist largely of terpenes.

Baker and Smith (5) have examined the oils of *E. accedens* W. V. Fitzg., *E. calophylla*, *E. cornuta* Labill., *E. diversicolor*, *E. gomphocephala* DC., *E. Lehmanni* (Preiss.) Schau., *E. longicornis* F. Muell., *E. marginata* Sm., *E. megacarpa* F. Muell., *E. occidentalis* Endl., *E. platypus* Hook., *E. redunca* Schau., *E. rudis* Endl., *E. salmonophloia* F. Muell. and *E. salubris* F. Muell. *E. platypus* (6) has also been examined by Earl, whilst Phillips (7) has investigated the oils of *E. campaspe* and *E. spathulata* Hook. Further species which have been examined include *E. Flocktoniae* Maiden (8), *E. Kesselli* Maiden et Blakely and *E. dundasi* Maiden (9), *E. salmonophloia* and *E. tetragona* F. Muell. (10), *E. oleosa* F. Muell., *E. eremophila* Maiden and *E. leptopoda* Benth. (11), *E. astringens* Maiden and *E. pyriformis* Turcz. (12), *E. concinna* Maiden et Blakely (13) and *E. erythronema* Turcz. (14). Mr. H. V. Marr (priv. comm.) has made available the following information from investigations carried out by Messrs. Plaimar Ltd.:—*E. uncinata* Turcz. (yield up to 1.4 per cent., cineole content up to 75 per cent.); *E. leptophylla* F. Muell. (yield about 1.2 per cent., 50 to 65 per cent. cineole); *E. Sargenti* Maiden (yield 1.4 per cent., about 60 per cent. cineole); *E. Formanii* C. A. Gardn. (yield about 1 per cent., about 45 per cent. cineole); *E. conglobata* (R. Br.) Maiden, *E. calycogona* Turcz. and *E. incrassata* Labill. give low yields of oil which contain only small amounts of cineole; *E. gracilis* F. Muell. (yield up to 1.3 per cent., 60 to 75 per cent. cineole) and *E. spathulata* which yields up to 1.6 per cent. of oil of which 50 to 65 per cent. is cineole.

Some of these oils are of obvious potential value as sources of medicinal eucalyptus oil. Others of similar value are *E. erythronema, E. leptopoda* and *E. concinna*. The initial cost of collecting leaves and small branches is a limiting factor in the successful exploitation of any oil bearing species and it is therefore essential that reasonably extensive, closely packed areas be available. It is this factor which has prevented the exploitation of some of our better species of *Eucalyptus*. A possible solution of this difficulty has been suggested by Mr. C. A. Gardner, who considers that species like *E. erythronema*, which has largely been cut out from the wheat belt, could be satisfactorily cultivated and could at the same time be made to serve the extremely useful purpose of preventing soil erosion.

Other genera of the family Myrtaceae yield oils which show some general resemblances to those of *Eucalyptus*, notably *Melaleuca* and *Agonis*. There are nearly 100 species of the genus *Melaleuca* in Western Australia, of which only six have been investigated, two of them for their cineole content alone. *M. leucadendron* L. is well known as the source of commercial cajuput oil. *M. uncinata* has been examined in some detail by Penfold (15) and K. E. Murray (16) and many samples have been examined by Plaimar Ltd. (H. V. Marr, priv. comm.). The species exists in at least three physiological forms, one of which grows preferentially around the low margins of lakes from Ballidu to Lake Grace. This form, which is generally arborescent, gives a low yield of oil which consists largely of terpenes and contains little or no cineole. A second form favours higher ground, particularly in granite country, and gives a much higher yield of oil of which from 75 to 85 per cent. is cineole. The third form resembles closely that described by Penfold from New South Wales.

Murray (*loc. cit.*) has also examined the oils of *M. lateriflora* Benth. var. *elliptica* Benth. and *M. rhaphiophylla* Schau. The former contains a high proportion of hydrocarbons and an unidentified phenol; the latter also contains a high proportion of hydrocarbons including α- and γ-terpinene, probably *p*-cymene, sesquiterpenes and an unidentified hydrocarbon, together with the alcohol Δ^1-terpinenol-4 and sesquiterpene alcohols.

The oils of *M. laxiflora* Turcz. and *M. Websteri* S. Moore have been examined by Messrs. Plaimar Ltd. for their cineole content.

The oil of *Calythrix tetragona* Labill. (17) has been investigated by Penfold, Ramage and Simonsen, and shown to consist largely of esters, notably citronellyl formate and the methyl esters of geranic and probably citronellic acids, together with pinene and citronellol. From the oil of *C. tetragona* var. *A*, Penfold and Simonsen have isolated the ketone calythrone.

The only other genus of this family of which any species has been investigated fully is *Agonis*, *A. flexuosa* (Spreng.) Schau. having been examined by Parry and subsequently by Phillips (7). The oil contains up to 60 per cent. of cineole and shows a close general resemblance to the cineole-containing eucalyptus oils.

A preliminary examination of the oil of *Chamaelaucium uncinatum* Schau. has shown it to consist mainly of terpenes, principally pinene, together with an aldehyde, probably citronellal, alcohols and esters, including amyl acetate.

Further genera of this family are known to produce volatile oils and the following should be worthy of investigation:—*Leptospermum*, *Callistemon*, *Baeckea* and *Darwinia*.

FAMILY RUTACEAE.

The family Rutaceae is also of importance as an oil producer. The well known *Boronia megastigma* Nees is the only member of its genus to be examined chemically, Penfold (18) having shown the presence of β—ionone and an unidentified alcohol as the chief odoriferous constituents, with triacontane, plant sterols and fat as the natural fixatives.

Penfold (19) has also examined the volatile oil of *Geijera linearifolia* (DC.) J.M. Black, the only representative of this genus in this State.

Both the leaf and fruit oils of *Phebalium argenteum* Sm. have been examined by Finlayson (20) and shown to consist mainly of terpenes (principally *d*-limonene) and sesquiterpenes, together with smaller amounts of geraniol, *l*-citronellol and two unidentified sesquiterpene alcohols, esters of valeric and *n*-caproic acids and methylheptyl and methylnonyl ketones. Murray (16) has examined the leaf oil of *P. filifolium* Turcz. and has shown it to consist largely of hydrocarbons with small amounts of esters, alcohols and possibly a phenol. About 32 per cent. of the oil consisted of an unidentified hydrocarbon, $C_{10}H_{16}$, b.p., 159-161°, from which no crystalline derivatives could be obtained. Murray states that the oils of *P. microphyllum* Turcz. and *P. Drummondii* Benth. appear similar to that of *P. filifolium*. The genera *Phebalium* and *Eriostemon* are closely related but, although some Eastern Australian species of *Eriostemon* are known to yield oils of interest, none of the Western Australian species has been examined.

FAMILY LABIATAE.

This family is equally well known on account of its volatile oils. The chemistry of the oils of the introduced plants *Mentha piperita* L., *M. pulegium* L. and *Rosmarinus officinalis* L. has been thoroughly worked out, but little work has been done on indigenous species. Hurst (21) records a private communication from A. R. Penfold that the oil of *Mentha australis* R.Br. consists largely of unidentified ketones, together with some alcohols and esters equivalent to about 12 per cent. of menthol. *M. satureioides* R.Br. (21) is, like *M. australis*, considered toxic to stock and Maiden (22) states that the oil is similar in properties to the oil of *M. pulegium*. Jones and Smith (23) have shown that it contains about 40 per cent. of pulegone as well as 1-menthone, 1-menthol and menthyl acetate.

All the Eastern Australian species of *Prostanthera* are oil bearing but none of the Western Australian species has been investigated. Maiden (22) mentions that *Ocimum sanctum* L. occurs in two varieties, the Northern Australian variety having an odour of anise and the Eastern variety that of cloves.

Family Coniferae.

As in the rest of Australia, the chief Western Australian genus of this family is *Callitris*. Of our seven species, only one (*C. Roei* (Endl.) F. Muell.) has not been examined at all. Baker and Smith (24) have examined the leaf oils and in some cases the fruit oils of *C. Drummondii* (Parlat.) F. Muell., *C. glauca* (R.Br.) Mirb. *C. intratropica* (F. Muell.) R. T. Baker, *C. robusta* (R Br.) Mirb. and *C. verrucosa* (R.Br.) Mirb. Finlayson (25) has also examined the fruit oil of *C. verrucosa* and Murray (16) has examined the leaf oil of *C. Morrisoni* R. T. Baker. The oils consist largely of the terpenes pinene, *d*- and *l*-limonene and dipentene, together with small amounts of alcohols such as geraniol and borneol and their esters with acetic and occasionally butyric acid. The wood of these species is resistant to termite attack and the chemistry of the wood oils warrants further investigation. Baker and Smith showed the presence of the sesquiterpene alcohol guaiol in the wood of most species, particularly *C. intratropica* and Trikojus and White have discussed the chemistry of the constituents of the wood oils (26) and the chemistry of guaiol (27).

The only other coniferous genera in Western Australia are *Podocarpus* and *Actinostrobus*. Baker and Smith (24) distilled the leaves of *P. Drouyniana* F. Muell. without obtaining any oil but from the leaves of *A. pyramidalis* Miq. they obtained a small yield of oil which consisted mainly of *d*-pinene with a small amount of esters. The remaining species of *Actinostrobus* have not been examined, but it is of interest to note that the oleo-resin secreted at the base of the columella of *A. glaucus* C. A. Gardn. MS is used on account of its healing properties.

Other Families.

Marr (28) has shown that *Stirlingia latifolia* (R.Br.) Steud. (Proteaceae) produces an oil which consists almost entirely of acetophenone. Oil of chenopodium is well known for its use as an anthelmintic and Shapter (29) has shown that distillation of *Chenopodium ambrosioides* L. var. *anthelminticum* (L.) A. Gray (Chenopodiaceae) growing in Victoria and New South Wales gives an oil of satisfactory ascaridole content. Local distillation of the plant, however, failed to give a satisfactory yield on one large scale run. *Alyxia buxifolia* R.Br. (Apocynaceae) is well known to bushmen as a cure for dysentery; the sending of a specimen of its oil to America some years ago resulted in a request for several pounds of the material, but no information is available as to its chemical nature. A preliminary empirical examination of the wood oil of *Myoporum serratum* R. Br. (Myoporaceae) has been published by Hill (30). The volatile oil from *M. deserti* A. Cunn. ex Benth. has been shown by Albert (31) to contain a large percentage of an unidentified ketone. The introduced *Foeniculum vulgare* Mill. (Umbelliferae) grows abundantly in parts of the metropolitan area but, although its oil has been thoroughly examined in other parts of the world, no analysis has been made of the local fruit oil. Finally mention might be made of the pungent, acrid volatile oil, described by Watt and Breyer-Brandwijk (32), which is obtained from *Anagallis arvensis* L. (Primulaceae).

III.—RESINS AND GUMS.

The only resins which have received any detailed attention from a chemical point of view are those of the different species of *Xanthorrhoea*. Herbert (33) has summarised the work done on *X. Preissii* Endl. up to 1920, while Rennie (34) reviewed the results from several species up to 1926. Finlayson (35) has described the results of an investigation of the resin from *X. reflexa* D. A. Herbert, by the method of steam distillation from alkaline solution, while Holloway (36) has compared the melting and decomposition points of the resin from *X. Preissii* with those of the resins of Eastern States species and has studied the effects of extraction of the different resins with a variety of solvents.

Strevens (37) has contributed a series of articles on the technology of the *Xanthorrhoeae* and Steel (38) has described the destructive distillation of the resin on a commercial scale.

A preliminary investigation of the resinous exudate of the turpentine bush of the Kimberley, *Grevillea pyramidalis* A. Cunn. ex R. Br. var. *leucadendron* (R.Br.) C. A. Gardn., has been made by Hill (39, sub. *G. leucadendron*). This exudate is apparently similar to that from *G. viscidula* C. A. Gardn. which is used by the natives, after mixing with ashes, for rubbing into tribal scars for the production of prominent cicatrices. The occasional abundant production of a hard reddish brown resin by *G. striata* R. Br. is recorded by Maiden (22), who also mentions the formation in quantity of a clear yellowish gum-resin on the branchlets of *Bertya Cunninghamii* Planch.

The production of resins by species of the family Convolvulaceae, particularly those of the genera *Ipomoea, Operculina* and *Convolvulus*, is well known. *Ipomoea hederacea* N. J. Jacq. and *Operculina Turpethum* (L.) S. Manso have been used as purgatives on account of their resin content and doubtless other members will be found to contain appreciable amounts of resin. Hurst (21) records that *Ipomoea polymorpha* R. et S. (sub. *I. heterophylla* R. Br.) is suspected of being poisonous in New South Wales, a reputation which might well depend on the presence of resin in the species. The resins produced by our Gymnospermae have received little, if any attention.

No chemical work appears to have been done on any of the gums. All species of *Acacia* produce gum probably of the arabic type, notably *A. microbotrya* Benth. and *A. Farnesiana* Willd., which is the source of Karachi gum from Sind. Maiden (22) mentions the copious production of gum by *Albizzia procera* (Willd.) Benth. and also refers to a high grade product obtainable from *Pittosporum phillyreoides* DC. The Christmas tree, *Nuytsia floribunda* (Labill.) R. Br., sometimes produces a considerable amount of gum in very large tears. A study of these gums, of the seasonal variation in their formation and of the methods used to obtain nearly colourless products, might well lead to the establishment of a profitable minor industry.

The gum-like or gelatinous substances obtainable from seaweeds are becoming increasingly important in many industries. The highly gelatinous nature of *Eucheuma speciosum* J. Ag., the "jelly plant" of Western Australia, was commented on as early as 1887 by Maiden, and the alga has been used locally in canning as a substitute for agar. Unfortunately the production of agar from this species does not appear possible since, on thawing the frozen jel, the water does not escape but is almost completely reabsorbed. The seaweed itself, however, could be utilised in industry in washed and bleached form since it requires only about fifteen minutes boiling to effect complete disintegration and solution as compared with the eight to ten hours needed by the *Gelidium* and *Gracilaria* species commonly used to make agar. Longer boiling of *Eucheuma speciosum* leads to rapid loss of gelatinising properties. The investigation of Eastern States seaweeds is being carried out by the C.S.I.R. (40) and there is need of similar work on Western Australian species, particularly those occurring from Carnarvon or Geraldton southwards.

IV. TANNINS AND KINOS.

A reasonably complete account of the tannin resources of Australia has been compiled through the efforts of numerous workers. The greater part of our information on Western Australian tanning materials was obtained as a result of a programme of work commenced in the Forest Products Laboratory of the Commonwealth Institute of Science and Industry in Perth and completed in the laboratories of the Forest Products Division of the C.S.I.R. in Melbourne. The main results of these and some few other investigations were published by Coghill (41) and by the Forests Department of Western Australia (42). Additional work was done by Maiden (22), Smith (43), Mann (44) and Baker and Smith (24). The principal genera covered in this work are *Acacia, Eucalyptus, Callitris* and *Banksia*, but representatives of numerous other genera are also included.

The production of tannin extracts was investigated by the C.S.I.R. in a pilot plant at the Engineering School of the University of Western Australia. Many possible raw materials were examined and, in particular, much work was done on karri bark which is available in quantity as a mill waste product. This extract, however, is not a suitable tanning material. The plant was taken over in 1932 by Industrial Extracts Ltd. and this company is now producing a very satisfactory extract from the wandoo, *Eucalyptus redunca* Schau. var. *elata* Benth. Some interesting comparisons of this extract with other commercial extracts have been published by Pound and Quinn (45).

Little work has been done on the chemistry of these tannins. Rennie (34) has briefly summarised the work which has been done on the tannins associated with the kinos of Eastern States species of *Eucalyptus* and Phillips (46), in an account of the kino of *E. calophylla*, has reviewed the chemistry of its tannin and has critically examined the work of McGookin and Heilbron (47). Blockley, Spiers and Beverley (48) have examined the wandoo extract which they consider to be a mixture of pyrogallol and catechol tannins, the former predominating.

V. POISON PLANTS.

Although Western Australia occupies an unenviable position in possessing more than her fair share of Australia's poison plants, little attention has been paid to the chemical nature of the toxic principles of these plants and such studies offer an almost unlimited field of research for the chemist.

(a) GLYCOSIDES.

(i) *Cyanogenetic Glycosides.*

The group of poison plants on which most work has been done is the cyanogenetic group. Such plants are widely distributed geographically and they occur in many families. In Australia Petrie and Finnemore have made great contributions to our knowledge in this field and much work has been done in South Africa and India on plants which are known in Australia. Hydrolysing enzymes are absent in a few species while from others the cyanogenetic glycosides have been isolated and their identity determined.

The following have been shown to be cyanogenetic:—*Acacia Cunninghamii* Hook. (no enzyme), *A. Oswaldi* F. Muell.; *Amaranthus viridis* L.; *Asplenium flabellifolium* Cav.; *Bothriochloa Ewartiana* (Domin.) C. E. Hubbard, *B. intermedia* (R. Br.) A. Camus; *Cardamine dictyosperma* Hook.; *Chenopodium Blackianum* Aellen, *C. carinatum* R. Br., *C. cristatum* (F. Muell.) F. Muell.; *Chloris truncata* R. Br.; *Chrysopogon fallax* S. T. Blake; *Colocasia antiquorum* Schott; *Cynodon dactylon* (L.) Pers.; *Cyperus distans* L.f.; *Dactyloctenium radulans* (R. Br.) Beauv.; *Digitaria sanguinalis* (L.) Scop.; *Dodonaea viscosa* (L.) Jacq.; *Drosera peltata* Sm., *D. gigantea* Lindl.; *Eremophila maculata* F. Muell. (49) and *Eucalyptus cladocalyx* F. Muell. (50), from both of which Finnemore isolated prunasin; *Euphorbia Drummondii* Boiss.; *Flagellaria indica* L.; *Goodia lotifolia* Salisb. (51), from which Finnemore isolated a glucoside of *p*-hydroxybenzaldehyde cyanhydrin; *Heterodendron oleaefolium* Desf., the leaves of which are always cyanogenetic, although Dr. H. W. Bennetts (priv. comm.) does not consider the plant toxic in Western Australia; *Indigofera australis* Willd.; *Ipomoea dissecta* Willd.; *Leptochloa digitata* (R. Br.) Domin.; *Lindsaya linearis* Swartz;*Linum marginale* A. Cunn. ex Planch.; *Lolium perenne* L.; *Lotus australis* Andr., from which Finnemore (52) isolated lotaustralin, the glucoside of methylethylketone cyanhydrin; *Neptunia gracilis* Benth.; *Passiflora foetida* L.; *Pomax umbellata* Soland.; *Poranthera ericoides* Klotzch, *P. microphylla* Brougn.; *Schizoloma ensifolium* J. Sm.; *Sisymbrium orientale* L.; *Sorghum halepense* (L.) Pers.; *S. sudanense* (Piper) Stapf.; *S. verticilliflorum* (Stend.) Stapf.; *Themeda australis* (R. Br.) Stapf.; *Trema amboinensis* (Willd.) Blume; *Trianthema crystallina* Vahl.; *Trifolium repens* L., shown by Finnemore (53) to contain lotaustralin; *Vicia sativa* L.

The following are suspected of being cyanogenetic from post mortem examination but have not so far shown to be so in the laboratory:—*Euphorbia boöphthona* C. A. Gardn., *E. clutioides* (Forst. f.) C. A. Gardn. and *Olax uliginosa* (Klotzsch) Klotzsch.

The additional genera are known to contain cyanogenetic species and might repay investigation:—*Adenia, Aristida, Danthonia, Halorrhagis, Juncus* and *Sporobolus.*

Finnemore has found no evidence of the production of hydrocyanic acid in *Acacia aneura* F. Muell., *A. brachystachya* Benth., *A. Drummondii* Lindl., *A. Farnesiana, A. Graffiana* F. Muell., *A. hakeoides* A. Cunn., *A. ixiophylla* Benth., *A. pentadenia* Lindl., *A. rostellifera* Benth., *A. salicina* Lindl., *A. saligna* Wendl., *A. undulifolia* Fraser, *A. urophylla* Benth.; *Eremophila longifolia* F. Muell., *E. bignoniiflora* F. Muell.; *Bryonopsis laciniosa* (L.) Naud.; *Didiscus glaucifolius* F. Muell. and *Trifolium dubium* Sibth.

Although no toxic principle has been isolated from the Western Australian species of *Macrozamia*, the isolation by Cooper (54) of macrozamin from the Eastern States species *M. spiralis* (R. Br.) Miq. may give a lead in the solution of the wider problem. Macrozamin does not give hydrocyanic acid by hydrolysis with acids, almonds or yeast, but it does so after hydrolysis with alkali followed by acidification. Malloch (55) has examined the outer coat and the endosperm of the seeds of *M. Riedlei* (Gaud.) C. A. Gardn. and has shown that the toxic substance is present in the endosperm. Malloch obtained no evidence of the presence of a saponin, glycoside or alkaloid and suggested that the toxicity might be due to the presence of a toxalbumen.

(ii) *Saponins.*

Saponins are probably as widely distributed as the cyanogenetic glycosides and they are of considerable importance not only on account of their toxic properties but also because of their value as emulsifying agents.

Ewart (56) has isolated a powerfully haemolytic saponin from *Atalaya hemiglauca* (F. Muell.) F. Muell. ex Benth., the whitewood of our North West, which is responsible for walkabout disease in stock. New South Wales specimens of this species are much less toxic than material from the vicinity of Fitzroy Crossing and Ewart has suggested that possibly two or more saponins of varying toxicity may be present in varying proportions in material from different localities. The saponin is stable and retains its toxicity for months. Dr. H. W. Bennetts (priv. comm.) has commented on the similarity between the toxic symptoms caused by *A. hemiglauca* and by *Senecio* species. This is of interest since the poisonous principles of the latter are alkaloids.

Acacia Cunninghamii (21), in addition to being cyanogenetic, is of interest in that its unripe pods contain about 3 per cent. of a highly toxic saponin which resembles the mydriatic alkaloids in its properties, producing local anaesthesia, mydriasis and paralysis of accommodation. Hurst (21) also records references to the presence of toxic saponins in *Acacia delibrata* A. Cunn. ex Benth., *A. pulchella* R.Br. and *Dodonaea physocarpa* F. Muell.

The genus *Isotropis* contains some powerfully toxic species, notably *I. atropurpurea* F. Muell. from which Finnemore has isolated a saponin. *I. cuneifolia* (Sm.) Domin. var. *parviflora* Benth. has been proved toxic to sheep and *I. juncea* Turcz. to guinea pigs; there is strong field evidence against *I. cuneifolia* (Sm.) Domin., while *I. Drummondii* Meissn., *I. canescens* F. Muell. and *I. Forrestii* F. Muell. are considered toxic. There is no indication of the nature of the poisonous principles of these species.

Albizzia distachya (Vent.) Macbride is recorded by Maiden (22) as containing about 10 per cent. of saponin in its dried roots, while the blister bush, *Phebalium argenteum,* is considered to be very rich in saponins. *Anagallis arvensis,* the scarlet pimpernel, contains the highly toxic cyclamin in its roots and saponins are also recorded to be present in *Cardiospermum Halicacabum* L. (32), *Tetragonia expansa* Murr. (21) and *Trianthema crystallina* Vahl. (21).

The caustic vine, *Sarcostemma australe* R.Br., is of interest because, although it has been proved toxic to stock and to laboratory test animals (57) in the Eastern States, it is generally regarded as a most useful fodder plant in Western Australia. Finnemore has shown the absence of alkaloids and prussic acid from eastern material while Earl and his co-workers (58) have isolated a saponin which hydrolyses to give glucose and an aglucone, which in turn gives benzoic and cinnamic acids and the substance sarcostin which is considered to be probably a steroid.

Other indigenous plants known to contain saponins are *Trymalium spathulatum* (Labill.) Ostf. and *Pittosporum phillyreoides*.

(iii) *Other Toxic Glycosides.*

The cape tulips *Homeria collina* Vent. and *H. miniata* Sweet are both toxic, the latter having a digitalis-like action on the heart, constricting blood vessels, raising blood pressure and having a curare-like action on voluntary muscle. Watt and Breyer-Brandwijk (32) record the isolation by Mackenzie of a glycoside from *H. miniata*. but Clarke (59), in stating that the poison occurs in all parts of the plant, considers it to be probably an alkaloid. *Raphanus raphanistrum* L. is an irritant poison to stock when taken in excess and is recorded by Steyn (60) as containing a sinalbin-like glycoside together with the hydrolysing enzyme myrosin. *Plantago major* L. (32) contains aucubin in most parts of the plant. The recorded isolation (61) of carissin, which resembles strophanthin in its action, from the bark of *Carissa ovata* R.Br. is of interest and suggests that *C. lanceolata* R.Br. might be worth investigation.

(b) ALKALOIDS.

Alkaloids are not as widely distributed through the plant kingdom as are members of the preceding groups, but when they do occur, they frequently do so in groups of related substances distributed through plants which are closely related botanically. Thus alkaloids of the berberine type are distributed through many families of the adjacent orders Ranales and Rhoeadales, while individual families like the family Solanaceae are particularly rich in alkaloids, in this case of more than one type.

In the family Solanaceae, the genus *Duboisia* is of outstanding importance. In the Eastern States, *D. myoporoides* R. Br. and *D. Leichhardtii* (F. Muell.) F. Muell. have been fairly recently developed as major sources of hyoscine and hyoscyamine. *D. myoporoides* appears to exist in two physiological forms, in one of which (that which occurs in Queensland and in New South Wales north of Gosford) hyoscine predominates, while in the other, the southern form, hyoscyamine is the principal alkaloid. Hyoscyamine is, however, more readily recovered from *D. Leichhardtii* which contains about 3 per cent. of the alkaloid in its leaves.

D. Hopwoodii, the only species of the genus occurring in Western Australia, has been examined by numerous workers. This plant, the pituri or chewing narcotic of the aborigines, was first examined chemically by Bancroft who showed that the alkaloid it contained was different from that occurring in *D. myoporoides*. Von Mueller, in 1879, concluded that the alkaloid was similar to but not identical with nicotine. The name piturine was given to the alkaloid but it was subsequently shown to give reactions similar to those of nicotine. The identity of the alkaloid appeared to be satisfactorily settled when Rothera in 1910 isolated only nicotine from a specimen of pituri identified by Ewart as consisting of *D. Hopwoodii*. Doubt was cast on the accuracy of this work when it was subsequently learned that, in parts of South Australia at any rate, pituri was not always obtained from *Duboisia* alone and the suggestion was put forward that the material examined by Rothera contained an appreciable amount of dust from the easily powdered leaves of *Nicotiana excelsior* J. M. Black (62). A re-examination of material from South Australia led to the isolation of *d*-nornicotine by Späth (63) with no indication of the presence of nicotine. This material, however, had been wet by heavy rain and had been kept damp for some considerable time, leading to partial racemisation of the nornicotine. It is quite possible that demethylation of any nicotine present may have occurred at the same time.

As part of a programme drawn up by the Drug Panel of the Department of Industrial Development, Dr. D. E. White has carried out some preliminary work on *D. Hopwoodii* from the vicinity of Ajana. He has shown that the principal alkaloid present is nicotine and that nornicotine, if present at all, occurs only in very small amount. Subsequent work on material collected on varying soil types from the vicinity of Canna to a little south of Perenjori has shown that nicotine is always the predominant alkaloid but that occasionally the nornicotine content (calculated on the yield of the picrates) approaches very close to the nicotine content. The repeated statement that *D. Hopwoodii* from the Eastern States contains no nicotine can perhaps only be explained by the existence of physiological forms of the plant. The investigation is being continued.

Further genera of importance in this family are *Anthocercis*, *Anthotroche*, *Datura* and *Nicotiana*. *Anthocercis viscosa* R. Br. contains the oily alkaloid anthocercine (21) and *A. littorea* Labill. has been held responsible for the death of children. This and other species of the same genus, as well as the species of the closely related genus *Anthotroche*, require examination. The introduced *Datura Metel* L., *D. Tatula* L. and *D. Stramonium* L. have been thoroughly investigated in other parts of the world and Finnemore has examined Australian grown material. *D. Metel* has been shown to contain chiefly hyoscine with a little atropine or hyoscyamine and norhyoscyamine, *D. Stramonium* to contain hyoscyamine in the leaves and seeds and both hyoscyamine and hyoscine in the roots, while *D. Tatula* contains hyoscyamine and atropine. The maximum amounts of alkaloids recorded do not differ materially from the maxima recorded for Britain and elsewhere. *D. Leichhardtii* F. Muell. has not been examined in Western Australia.

Nicotiana glauca Grah. has been investigated by many workers and has until recently been considered to contain only nicotine to the extent of something less than one per cent. Quite recently, Smith and Smith (64) have shown that anabasine makes up about 97 per cent. of a total of little more than 0.6 per cent. of alkaloids and that nicotine is present only in very small amount. *N. suaveolens* Lehm. was recognised by Staiger in 1886 as containing a volatile alkaloid which resembled nicotine. This alkaloid was considered to be the toxic principle of the plant until Smith and Smith (*loc. cit.*) showed it to contain both nicotine and nornicotine, the latter making up about 65 per cent. of a total of less than 0.5 per cent. of alkaloids. *N. excelsior* does not appear to have been examined chemically. It is used by the aborigines, as is *Duboisia Hopwoodii*, as an emu and kangaroo poison, and Hicks (62) records its use as a chewing narcotic.

The genus *Solanum* is the largest of the family Solanaceae in Western Australia. Many of its members contains the high molecular weight alkaloids of the glycosidic steroid type such as solasonine (solanine-s), and are therefore more or less toxic. *S. chenopodinum* F. Muell. (21), *S. nig-*

rum L. (32) and *S. sodomaeum* L. (65) are all recorded as containing solasonine or "solanine" and, in addition, *S. nigrum* is said to contain a tropine alkaloid which possesses mydriatic properties. *S. Sturtianum* F. Muell. is also recorded (21) as being markedly toxic to sheep and probably containing "solanine".

The order Leguminosae is very well represented in the Western Australian flora and, in the world as a whole, it provides more substances of medicinal importance than any other order. In the family Papilionaceae, *Crotalaria retusa* L. has been shown (66) to contain the alkaloid monocrotaline. This is of considerable interest because it establishes a relationship with the senecio alkaloids, since on boiling with barium hydroxide solution it gives retronecine as one of its decomposition products. *C. dissitiflora* Benth. has been found by Finnemore to contain an alkaloid and *C. Mitchelli* Benth., which is suspected of being poisonous, might well contain alkaloids. *Indigofera boviperda* A. Morrison has been proved toxic to cattle in Northern Australia and is suspected of containing alkaloids (67); *I. australis* has also been recorded as a stock poison.

The presence of alkaloids in the genera *Gastrolobium* and *Oxylobium*, which include perhaps the most toxic of Western Australian plants, was indicated by the work of Mann and Ince (68) who described the isolation of cygnine and lobine respectively from *G. calycinum* Benth. and *O. parviflorum* Benth. This has not been confirmed by other workers, but it has very recently received support to some extent by the demonstration by Dr. D. E. White of the presence of alkaloids in *O. graniticum* S. Moore. The solution of the problem has been simplified by Dr. H. W. Bennetts (69) who has demonstrated that all the toxic members of the two genera produce the same series of symptoms provided the dose is modified according to the general toxicity of each individual plant. Further general information on these species is contained in references (69) to (73) inclusive.

Introduced plants in the family Papilionaceae include *Cytisus prolifer* L. and *Ulex europaeus* L., both of which contain cytisine, while among the *Lupini*, *Lupinus angustifolius* L. contains *d*-lupanine and *L. luteus* L. contains lupinine and sparteine as well as a glucoside. *L. hirsutus* L. is considered toxic in South Africa and is probably alkaloidal in nature.

The family Caesalpiniaceae is also known to contain alkaloids. *Erythrophleum chlorostachys* (F. Muell.) Hennings ex Taub., one of the so-called camel poisons, is exceedingly poisonous to most stock. Petrie and Priestly (74) have shown the absence of saponins and cyanogenetic glycosides in the plant and have isolated an alkaloid from it which has identical chemical and physiological properties to erythrophleine. *Caesalpinia Bonducella* (L.) Fleming is recorded (32) as containing an alkaloid in its seed and, in addition, it contains a bitter principle, bonducin, which is stated to be as effective as quinine in treatment of malaria.

The family Compositae is the largest in the plant kingdom and a number of its members contain alkaloids. Within recent years much work has been done, particularly in South Africa and Canada, on the alkaloids of the genus *Senecio*. This work has been reviewed by Waal (75), while more recent work has been published by the same author (76) and by Richardson and Warren (77). The introduced *S. vulgaris* L. contains senecionine and seneciine and is known to produce the typical symptoms of senecio poisoning, including cirrhosis of the liver. *S. lautus* Soland. is stated by Bennetts

(78) to be toxic and to have selective action on the liver, although subsequently the feeding of half a pound of the plant daily to each of two sheep for eight weeks failed to produce any evidence of liver cirrhosis (Bennetts, priv. comm.). Species of the closely related genus *Erechthites* are also known to contain similar alkaloids. In the same family, *Xanthium spinosum* L. is recorded (21) as containing an alkaloid with an intense action on the central nervous system, while *Brachycome graminea* (Cass.) F. Muell. has given doubtful positive reactions for alkaloids. The genus *Eclipta* is of interest since the Indian species *E. alba* Hassk. has been shown (79) to contain nicotine.

The seeds of *Strychnos lucida* R. Br. have been examined in New South Wales (21) and material from Kunmunya Mission in the Kimberleys has been shown (80) to contain both strychnine (about 0·8 per cent.) and brucine (about 1.5 per cent.). *Dodonaea viscosa* is recorded (32) as being used as a fish poison and to contain an alkaloid which has stimulant properties similar to those of coca. *Tetragonia expansa* has been found by Finnemore (21) to contain alkaloids in addition to the saponin already mentioned. *Crinum asiaticum* L. contains lycorine which is fairly widely distributed in the family Amaryllidaceae.

Among introduced plants, the chemistry of the alkaloids of the spotted hemlock, *Conium maculatum* L., has been thoroughly worked out. *Lolium temulentum* L. often contains a poisonous fungus (*Endoconidium temulentum*) in its seeds from which the alkaloid temuline was isolated by Hofmeister in 1892. The grass has been recorded by Carne and Gardner (81) as producing intoxication, particularly in pigs. The same fungus is believed to occur in rye grass, *L. perenne*. *Lithospermum arvense* L. contains the alkaloid cynoglossine which has a curare-like action, and possibly consolidine with which it is often associated. The cape lilac, *Melia azedarach* L., has been stated (82) to contain azaridine in its fruits. The alkaloid mesembrine has been isolated (83) from *Cryptophytum crystallinum* (L.) N. E. Brown and from more than twenty other species of this and related genera of the *Mesembryeae*. It resembles cocaine in its action but its local anaesthetic properties are much weaker. *Vicia sativa* contains the purine alkaloids vicine, convicine and vernine, the latter also being present in *Trifolium pratense* L. *Brassica nigra* (L.) Koch. contains sinapine in its seeds. In the family Papaveraceae, the introduced poppy, *Papaver hybridum* L. contains alkaloids and the Mexican poppy, *Argemone mexicana* L., contains berberine and protopine, but in neither of these, nor in *P. aculeatum* Thunb., is morphine present.

Among indigenous plants which suggest themselves for examination for alkaloids is a big group in the order Contortae from the families Apocynaceae and Asclepiadaceae. In particular, the genera *Alstonia*, *Wrightia*, *Asclepias*, *Cynanchum*, *Tylophora* and *Marsdenia*, of which numerous species are known to contain alkaloids, should be investigated. Of equal importance is the genus *Lobelia* and possibly *Isotoma* while other species worth consideration are *Erythrina vespertilio* Benth., *Sarcocephalus coadunatus* (Sm.) Druce and possibly *Dioscorea hastifolia* Endl. and *Salsola Kali* L.

(c) PLANTS CONTAINING NITRATES.

The presence of nitrites in plants can give rise to toxic symptoms in animals through the conversion of haemoglobin into methaemoglobin, so interfering with the oxygen carrying capacity of the blood. Nitrates, through enzymic reduction, are capable of producing the same effects. *Tribulus terrestris* L. has been shown in South Africa (84) to contain a little nitrite and an appreciable amount of nitrate, and its poisoning symptoms are those of acute asphyxia. The spotted thistle, *Silybum Marianum* (L.) Gaertn., has been known to contain up to 25 per cent. of potassium nitrate, calculated on a dry basis, and its toxicity is almost certainly due to the reduction of this nitrate to nitrite with the resultant conversion of haemoglobin into methaemoglobin. It seems possible that the toxicity of *Cynodon Dactylon* may be due in part to a similar cause, and the possibility may be extended to *Erythrina vespertilio* since some species of this genus are known to contain nitrites.

(d) Photosensitising Plants.

Photosensitisation of stock does not seem to be of the same importance in this State as it does in South Africa or in the Eastern States and New Zealand. Steyn and van der Walt (85) have shown that *Lantana Camara* L. is toxic and produces photosensitisation, while Louw (86) has isolated lantanin from the plant and established it as the photosensitising agent. Steyn and van der Walt (*loc. cit.*) also record the isolation of a trace of an alkaloid from *L. crocea* Jacq. which produced the characteristic symptoms of poisoning by this plant. Quin and Rimington have shown in South Africa that the photosensitising action of *Medicago denticulata* Willd. is due to the production of phylloerythrin from chlorophyll in the rumen of the animal either by bacterial or protozoan activity. The effect produced by *Tribulus terrestris* is attributed to the same cause and both *Medicago minima* (L.) Grufb. and *Chloris truncata* are similarly suspected. It should be noted, however, that the photosensitising action of St. John's wort, *Hypericum perforatum* L. var. *angustifolium* DC., is due to the presence of a mixture of closely related pigments, called hypericin, which in very low concentration produces haemolysis on exposure to light of suitable wave length (21; 87). *Panicum effusum* R.Br. (21; 60) is also photosensitising, but no work appears to have been published on the chemical aspect of this action. *Trifolium hybridum* L. and *T. pratense* are both recorded by Steyn (60) as producing photosensitisation.

(e) Fish Poisons.

Fish poisons have been used for centuries by natives in different parts of the world and many such materials from Central and South America, tropical Africa, India, Malaya, the East Indies and the Pacific Islands have been examined systematically by numerous workers to determine their insecticidal value. Through the influence of the paleotropic flora on Australian vegetation, an influence which extended down the eastern portion of Africa, it is reasonable to expect that fish poisons similar to those found in Indo-Melanesia and East Africa will be found among our own northern and north-western flora.

No species of the outstanding genera *Derris* and *Lonchocarpus* are known in this State, but several genera which are known to contain the same active principles as *Derris* do occur in the North-West and Kimberleys. Thus some species of *Tephrosia* have considerable local use as insecticides in other parts of the world although they are admittedly not as effective as *Derris*. In Western Australia there are sixteen species of *Tephrosia*, of which two, *T. purpurea* Pers. and *T. rosea* F. Muell. ex Benth., are known to be poisonous. These two species at least should be investigated for their insecticidal value. In the same category is the genus *Barringtonia* and possibly the genus *Terminalia*.

The bark of *Careya australis* F. Muell. is used as a fish poison in Queensland and Northern Australia and material from Arnhem Land has been examined (88) for insecticidal properties but found to be without toxic effects on *Aphis rumicis*. The bark of *Acacia salicina* is recorded by Hurst (21) as being used as a fish poison.

(f) MISCELLANEOUS POISONS.

Abrus precatorius L. contains two toxic proteins, a paraglobulin and a phytalbumose, the mixture being known as abrin. Abrin is not necessarily poisonous when taken orally but it is highly toxic when injected. It has been used therapeutically in treatment of opacity of the cornea and granulation of the eyelids, but the inflammation it produces is dangerous and sometimes difficult to control. The introduced *Cucumis myriocarpus* Naud. has frequently been reported toxic to stock and human beings. Finnemore has shown the absence of prussic acid and South African workers have separated several toxic materials from the fruit. Quin isolated in 1928 a non-alkaloidal, non-glycosidal substance which was highly toxic to animals, whether given orally or by injection. In 1933 Rimington separated the amorphous very toxic substance cucumin from this and other species of *Cucumis*. Subsequently Rimington and Steyn (89) isolated the apparently pure compound $C_{28}H_{42}O_8$ and showed that it was probably a dilactone. *Pteridium aquilinum* (L.) Kuhn., the bracken, which is toxic to cattle and horses, is stated by Steyn (60) to contain pteritannic acid (identical with filicic acid from *Dryopteris Filix-mas*) as its main active principle.

Leonotus leonurus R. Br., which is smoked by natives in South Africa like Indian hemp and which produces a similar stupefying effect, is recorded by Watt and Breyer-Brandwijk (32) as containing a dark green resin which is probably responsible for the narcotic action. The same authors also refer to the separation of two phenolic substances from the reddish leaf oil. The prolonged blood-clotting time associated with the eating of *Melilotus alba* Desr. and probably *M. indica* All., is discussed by Hurst (21). The presence of coumarin has been shown to have a bearing on the ability of the clover to become toxic and a specific substance has been isolated from spoiled clover which inhibits blood-clotting.

Oxalic acid and oxalates are widely distributed in the plant kingdom, often in sufficient quantity to cause stock poisoning. Many species of *Rumex* and *Oxalis*, for example, contain enough to produce poisoning if eaten to excess and *Salsola Kali* is known to contain a considerable amount of the acid.

There are many plants which have been proved toxic but no information is available concerning their active principles. In some cases, a knowledge of the poisonous constituents of other species belonging to the same or to related genera may be of value as a guide, but in others there is little evidence to suggest possible lines of attack. Amongst the more important of these plants are *Anagallis femina* Mill., *Bryonopsis laciniosa*, *Cryptandra leucophracta* Schlecht., *Didiscus glaucifolius* F. Muell. (which contains neither alkaloids nor prussic acid), *Echinopogon* spp., *Malva parviflora* L., *Mimulus repens* R. Br., *Morgania glabra* R. Br., *Myoporum acuminatum* R. Br., *M. deserti, Pimelia flava* R. Br., *P. trichostachya* Lindl., *Sinapis arvenis* L., *Solanum ellipticum* R. Br., *Trema amboinensis, Velleia discophora* F. Muell. *V. panduriformis* A. Cunn., *Wedelia asperrima* (Dene) Benth., *Wikstroemia indica* (L.) C. A. May, *Zantedeschia aethiopica* Spreng. and *Zornia diphylla* Pers. Acrid, blistering and emetic latexes are produced by many members of the family Euphorbiaceae, including *Excaecaria Agallocha* L., *E. parviflora* Muell. Arg. and *Euphorbia Peplus* L.

Among the more important plants which are suspected poisons, but concerning which little definite information is available, the following are perhaps the most noteworthy:—*Acacia armata* R. Br., *Beyeria viscosa* (Labill.) Miq., *Carduus pycnocephalus* L., *Centaurea melitensis* L., *Centipeda minima* (L.) A. Braun et Aschers, *Didiscus pilosus* Benth., *Epaltes australis* Less., *Eremophila glabra* (R. Br.) Ostf., *E. Latrobei* F. Muell., *E. Sturtii* R. Br., *Goodenia glauca* F. Muell., *Gyrostemon Sheathii* W. V. Fitzg., *Inula graveolens* Desf. (32), *Lactuca saligna* L., *L. scariola* L., *Lavatera plebeia* Sims, *Microseris scapigera* (Forst. f.) Schultz et Bip. and *Ranunculus lappaceus* Sm.

VI.—DYES AND COLOURING MATTERS.

The greater part of the work which has been done on Western Australian plant colouring matters is unpublished work by Dr. D. E. White, who has kindly made available the following information. *Anigozanthos flavida* Red. contains cyanidin pentose glycoside; *A. Manglesii* D. Don, anthocyanin, possibly conjugated with tannin; *Boronia megastigma*, delphinidin pentose glycoside, partially methylated, together with some disaccharide; *Chamaelaucium uncinatum*, malvidin dimonoside; *Chorizema cordatum* Lindl., malvidin monoside; *Eucalyptus ficifolia* F. Muell., pelargonidin together with some cyanidin bioside; *Oxylobium lanceolatum* (Vent.) Druce, malvidin monoside. *Clianthus speciosus* (G. Don) Aschers et Graebn. from South Australia contains pelargonidin monoside in the red portion of the flower and cyanidin monoside in the black, while the partial white variant from western New South Wales contains peonidin monoside in the keel and pelargonidin monoside in the standard.

Maiden (22) records the presence of a red colouring matter, which is very sensitive to acids and alkalies, in the juice of the fruit of *Eugenia australis* Wendl., and Herbert (90) records similar colour changes with the flowers of several species of *Eriostemon* and *Boronia*. This is particularly noticeable in the case of *B. tenuis* (Lindl.) Benth., in which carbon dioxide in a moist atmosphere will change the colour from blue to pink.

Little is known concerning the colouring matters or dyes which occur in woods and barks. The yellow pigments of jam wood (*Acacia acuminata* Benth.) are referred to in the next section on vitamins, and Maiden (22) mentions the presence of a yellow dye in the bark of *A. subcaerulea* Lindl. A strong yellow colouring matter is also present in the wood of *Sarcocephalus coadunatus*. The wood of *Caesalpinia Bonducella* contains, as does that of many other species of the genus, the substance brasilin and its red oxidation product brasilien. Woods of this nature, like sappan and logwood, have long been used for dyeing.

VII.—VITAMINS.

Very little work has been done on the vitamin content of indigenous or introduced plants in Western Australia. Maiden (22) records that *Trigonella suavissima* Lindl. is an excellent antiscorbutic and that *Portulaca oleracea* L. is used for the same purpose and is apparently highly nutritious. *Rumex Acetosella* L. has been used in treatment of scurvy (32) but it may produce oxalic acid poisoning if eaten to excess. Hill (91) has determined the ascorbic acid content of various cultivated fruits and has obtained evidence of the presence of carotene in the petroleum ether extract of *Acacia acuminata* wood (92). This was confirmed by Trikojus and Drummond (93) who isolated pure β-carotene from the extract and obtained evidence of the presence of five other carotinoid pigments. These five fractions were examined spectroscopically but they were not pure enough for differentiation and identification. Underwood and Conochie (94) have determined the carotene content of a number of pasture species, some of which are indigenous.

VIII.—MEDICINAL SUBSTANCES.

A number of products which are or could possibly be used in medicine have already been referred to in their appropriate sections, notably eucalyptus and sandalwood oils, the seeds of *Strychnos lucida* and the *Alstoniae.* There are, however, a few which have been used medicinally, some of which appear to warrant vigorous exploitation, and many which require both chemical and physiological examination. *Euphorbia pilulifera* L., a tropical herb of wide distribution, is used in treatment of bronchitis and asthma. *Agropyron repens* (L.) Beauv. is used as a demulcent diuretic, and wattle bark and eucalyptus kino are employed as astringents.

Of some considerable importance are plants which are known to be of value in treatment of diarrhoea and dysentery. Outstanding among these is *Grewia polygama* Roxb., although it is not known whether it simply checks diarrhoea or will cure bacillary or amoebic dysentery. *Alyxia buxifolia* has already been mentioned in this respect, and the following are also used either in South Africa, India or Australia for the same purpose:—*Bidens bipinnata* L., *Erodium moschatum* (L.) L'Her., *Euphorbia alsinaeflora* Baill., *Evolvulus alsinoides* L. and *Melastoma malabathricum* L.

Bitter substances find considerable use in tonics and much dandelion root is normally imported, as well as many other drugs, for this purpose. There are, however, many bitters available in the State and there should be little necessity to import such substances. *Strychnos lucida* has already been mentioned and there are many members of the family Gentianaceae which might be profitably exploited. Among these are *Erythraea australis* R. Br., *Sebaea ovata* (Labill.) R. Br. and *Villarsia* spp. Additional bitters which might be employed are the *Alstoniae, Petalostigma sericea* (R. Br.) C. A. Gardn., *Marrubium vulgare* L. and *Codonocarpus cotonifolius* F. Muell.

Many *Cassiae* contain emodins and resins and consequently act as purgatives. The leaves of *C. Sophera* L. are used as a substitute for senna in some parts of India and the related Western Australian *Cassiae,* particularly *C. pleurocarpa* F. Muell., should be examined for similar properties. Other plants which have been used as purgatives are *Gratiola pedunculata* R. Br. and *G. peruviana* L., while the intensely bitter Afghan melon, *Citrullus vulgaris* Schrad., is almost certain to be a drastic purgative.

Extracts of *Erodium cicutarium* (L.) L'Her., which have a powerful effect on the uterus, resulting in an increase of contractile activity, have been used in Europe for arresting uterine haemorrhage. No compound with these properties has yet been isolated from the plant. Somewhat similar properties are possessed by *Adiantum aethiopicum* L., extracts of which are used by the Sutos for promoting parturition, and by *Pteridium aquilinum* which is used, along with the bulb of *Vernonia corymbosa,* as an abortifacient.

Diuretic properties are possessed by *Boerhaavia diffusa* L., *Indigofera enneaphylla* L. and *Trichodesma zeylanicum* (Burm. f.) R. Br., while the roots of *Hybanthus enneaspermus* (L.) F. Muell. are used in India for treatment of diseases of the urinary tract. *Plumbago zeylanica* L. and *Siegsbeckia orientalis* L. are recorded as powerful sudorifics, and *Erodium moschatum* also possesses diaphoretic and antipyretic properties.

Thespesia populnea (L.) Soland. ex Corr. is used for treatment of skin parasites and scabies in India, and in South Africa *Cassytha filiformis* L. is used to eliminate head vermin. *Hibiscus trionum* L. is employed as a remedy for round worms and the use of *Cheilanthes hirta* for the treatment of tape worm suggests that the local representatives of the genus should be examined. *Hydrocotyle asiatica* L. is listed by Hurst (21) as having a multiplicity of medicinal uses a few of which would appear to need some justification. *Cassia mimosoides* L. appears to possess sedative properties and it is used, in much the same way as hops, as a pillow, or under a mattress, to induce sleep. *Clematis microphylla* DC. contains irritant substances and may be used as a counter-irritant in the form of poultices. Reference has already been made to the quick healing properties of the oleo-resin in the fruit of *Actinostrobus glaucus*; similar properties are possessed by the leaves of *Cymbonotus Lawsonianus* Gaud., which, when extracted with lard, give a useful salve for dressing wounds.

Some lines of investigation which might lead to the recognition of useful medicinal plants have already been indicated. Others include the examination of the genus *Polygala* from which senega is obtained, the genus *Goodenia,* some species of which are used by gins for making children sleep on long journeys, the genus *Haemodorum,* some species of which are used by natives as purgatives, and likely members of the order Rhamnaceae, which might possess barks resembling cascara, and of the order Rubiaceae, many of which contain valuable alkaloids.

IX. WOOD DISTILLATION.

This review would not be complete without some reference to work which has been done on wood distillation. Almond, Holmes and Plant (95) have prepared and examined charcoals from dry and green saplings and mature trees of *Eucalyptus marginata* and from *E. redunca* var. *elata, E. salmonophloia* and *E. salubris.* They have also described (*loc. cit.*), charcoals prepared from *E. rostrata* Schlecht. from Victoria and New South Wales and from *E. alba* from Queensland. It is possible that the latter is identical with *E. platyphylla* F. Muell. The report of the Mines Department for 1940 contains proximate analyses of specimens of charcoal, obtained from local charcoal burners, prepared from *E. calophylla, E. marginata* and *E. redunca* var. *elata.* Gregson (96), in discussing some aspects of the use of charcoal as a fuel in gas producers, has given the results of the analysis of a number of samples of charcoal from *E. marginata* as well as calorific values for charcoal obtained from *E. calophylla, E. redunca* var. *elata,* "mulga" and "ti tree."

N. A. Hanley and J. F. Pearse have investigated, for the Iron and Steel Panel of the Department of Industrial Development, the distillation of the wood of *Eucalyptus calophylla, E. diversicolor, E. marginata* and *E. redunca* var. *elata,* as part of the preliminary work in connection with the establishment of a pilot plant for the production of charcoal iron at Wundowie. An examination was made of the composition of the liquid distillate and of the wood gas at varying temperatures and the relationship of the volatile content of the charcoal to the retorting temperature was studied in the case of *E. marginata.* It was found that *E. calophylla* gave the highest yields of methyl alcohol and acetic acid and that, while the yields of acetic acid were only slightly lower with *E. diversicolor* and *E. redunca* var. *elata,* these two species gave considerably less methyl alcohol. *E. marginata* gave much lower yields of both products. The results obtained from *E. calophylla* compared reasonably well with those from such North American hardwoods as beech and maple. From the point of view of charcoal production, highest yields were obtained from *E. marginata* and *E. redunca* var. *elata.*

X. CONCLUSION.

It should be clear from what has been said that there is an immense field open for the study of the native plants of this State, a field commanding the attention not only of chemists, but of botanists, agriculturalists, entomologists, pastoralists and manufacturers. There is no institution here in which pharmacological work is being carried out and there appears to be no one interested in ethnological aspects of our native tribes which might have bearing on some of the problems which have been indicated. Such facilities as do exist for chemical investigations are limited to a greater or lesser extent by the nature of the other work which must be performed in the institutions which enjoy these facilities. In consequence it is felt that too strong a plea cannot be made for the establishment of either a separate Government department or a branch of an existing department, a principal function of which would be the investigation of these problems. A start in a very small way has been made by the Department of Industrial Development in the establishment of a Drug Panel, but on its present footing this panel can contribute very little towards the solution of some of the major problems which have been indicated and which may take several years to solve. An appreciation of the results of the fruitful association of botanist and chemist as represented by the joint work of Baker and Smith and of the continued flow of valuable work from the Sydney Technological Museum, carries with it the conviction that we are neglecting a field of enquiry which must ultimately adequately repay any capital expenditure on buildings and equipment as well as salaries paid to new officers.

Essential requirements for such a new department or branch would include adequate housing of the State herbarium which should be extended to feature all products of possible technical importance, and the provision, preferably in the same building, of the necessary laboratory accommodation and equipment for carrying out the chemical investigations. Ground or floor space for small pilot plant investigations is also essential, as well as adequate space for gardens for cultivation and breeding experiments.

Until such provisions are made, our chemical knowledge of Western Australian flora must wait on such progress as can be made from our existing institutions, or on the activities of private firms which are naturally interested only in those plants which offer some prospect of immediate profitable exploitation.

In conclusion I should like to express my great appreciation and indebtedness to Mr. C. A. Gardner for the generous assistance he has given in establishing the names of the species mentioned in this address.

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